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The Chemical Composition, Digestibility, and
Feeding Value of Vegetable Ivory Meal

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VEGETABLE IVORY NUTS AND PRODUCTS.



From left to right:-

One pound of vegetable ivory meal.

An ordinary match to show relative proportions.

A nut from which button blanks have been turned.

Several buttons and dice of the same material lie at the foot of this nut.

A number of whole nuts showing variation in size.

A nut from which a portion of the outer shell has been removed.

A cross-section (extreme right) of a poor nut showing a core, cracked and wrinkled. The prevalence of these cores causes much waste.

THE CHEMICAL COMPOSITION, DIGESTIBILITY, AND

FEEDING VALUE OF VEGETABLE IVORY MEAL.

By

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Vegetable ivory, or Coroza nut, as it is commonly known in commerce, is the seed or nut of the palm-like plant, *Phytelephas macrocarpa*. It is a native of the Latin American countries, being found in great quantities along the banks of the Magdalena, Colombia, where it is known to the natives as Tagua. It is also found in Peru and in the forests of northern Ecuador. In appearance the plant itself is a stemless palm, bearing its fruit in conglomerate heads, often weighing twenty-five to thirty pounds apiece. These heads are made up of thirty to fifty seeds or nuts, varying in size from half an inch to several inches in diameter. In the earlier stages of growth the seed contains a clear insipid liquid, which later changes to a sweet milky paste, and finally hardens into the white horny substance from which it derives its name, vegetable ivory.

Large quantities of the nuts are imported annually by Great Britain, Germany and the United States,¹ principally for the manufacture of buttons. Beneath the brown outer coating the dried nut has the appearance of dentine ivory, and can easily be sawed, carved and turned into all sizes and shapes of buttons, while the texture is such that it readily absorbs dyes and will

¹ United States uses about 10,000 tons annually, costing one and one-half millions. Census 1909.

take a high polish. The nuts sell for about \$50.00 per ton¹ and statistics show that something like 20,000 tons are annually shipped from Ecuador alone, ~~while~~ other countries are yearly increasing their output.

In the process of manufacture a considerable portion² of the nut is wasted in the form of sawdust chips and turnings. In foreign countries this waste has been mixed with other ingredients to be used as a cattle food. German writers state that the vegetable ivory meal has been used to a large extent as an adulterant in the manufacture of so-called "concentrated feeds". Some instances are given where as much as fifty percent of this material has been added.³

In the last few years considerable attention has been attracted in this country by the enormous amount of waste material produced by button factories, and many attempts have been made to discover a practical use for the material, aside from fuel. Requests have been made at the Massachusetts Experiment Station for information regarding its use as a feeding material. As far as is known no digestion experiments have been carried out in the United States and no literature on the subject is available. For this reason the following work was undertaken.

Considerable work has been done on the chemistry of vegetable ivory, both in this country and in Europe. Tollens⁴, Fischer

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- 1 Nelson's Encyclopedia, Vol. 6, p. 539. More recent authorities state as high as \$80.00 per ton, green weight.
 - 2 About 80 percent of the green weight.
 - 3 Mageberger Zeitg. (1891) No. 286.
 - 4 Handbuch der Kohlenhydrate, Bd. II, 113.

and Hirschberger¹ and others have worked with ivory meal as a source of mannose and have otherwise investigated the material more or less thoroughly. In this country Hudson, Browne and other chemists have conducted considerable research with it. Many have attempted to use it for the production of lactic acid, alcohol, etc., evidently with no marked results. The most recent use to which it has been put is the manufacture of "Zipangu", a substitute for coffee.²

³
In 1890 Richard Niebling in his work with artificial digestion, among other things, experimented with vegetable ivory. In connection with this work he reports an instance of its being fed to sheep in a digestion experiment, conducted to compare its results with his data obtained by laboratory methods. This is the only record of actual digestion experiments with animals found by the writer, in which vegetable ivory meal was used.

No claim for originality is made in regard to the chemical work done on this material with the exception of the investigation of the so-called "Pectin", and the results of the experiments with Fehling's solution. The other analytical results compare closely with the work of other chemists and verify data already established. It is believed, however, that the digestive and feeding experiments are original, and that the data secured will prove of service to those interested in this material.

The vegetable ivory meal used in the experiments was obtained through the courtesy of Mr. Sigmond Saxe of New York City. Several tons were used in all. The material, as it came, already ground,

1 Ber., 22, 3218.

2 Ztschr. Offentl. Chem. 19 (1913) No. 14, p.p. 266-277.

3 Landw. jahrb. bd. 19, p.p. 149-188.

had the appearance of a medium fine meal, white in color, though flecked here and there with particles of the brown outer coating of the nut. It was tasteless, odorless and very hard, being almost gritty to the touch.

The Chemical Composition of Vegetable Ivory Meal with
Especial Reference to Its Carbohydrates.

Preliminary to the study of the chemical composition of the ivory meal, ordinary fodder analyses¹ were made, and at a glance the following table will show, not only the variations met with in different samples, but that by far the greater part of the material is carbohydrate in nature.

Table I.
Fodder Analyses.

	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u> ²	<u>German Analyses for Comparison</u> ³
Moisture	12.64	6.13	11.39	18.30 - 13.20
Ash	2.30	0.80	1.08	1.30 - 1.10
Protein	5.26	3.94	4.63	4.60 - 4.00
Fat	1.18	0.60	0.92	1.10 - 0.80
Fiber	7.75	6.13	6.89	79.80 - 75.80
Nitrogen free extract	77.56	74.17	75.09	

As three-fourths of the entire product is nitrogen-free extract it was to this portion that most of the attention was given. The other constituents will merely be mentioned as follows:

Moisture. Moisture determinations were made by weighing 5 grams of the finely ground material into glass weighing bottles and drying over night in an electric oven at 100° C.

Ash. Ignition of 2 grams in a porcelain crucible at a very

1 Official methods.

2 Average of nine samples.

3 Landw. Wochenblatt f. Schleswig-Holstein 1886, p.p. 255 and 353.
Also Reichardt Journal f. Landwirtschaft 40, p. 11.

low heat readily produced a fine white ash. No attempt to analyze the ash was made, except to test for iron, which was found to be present. An analysis of "Vegetable Ivory Refuse" printed in the Annual Report of this Station for 1890 gives data on the mineral content as follows:-

Table II.

Moisture at 100° C.	8.140
Organic and volatile matter	93.580
Ash	6.420
Ca O	4.842
Mg O	0.430
Fe ₂ O ₃	0.043
Na ₂ O	0.125
K ₂ O	0.461
P ₂ O ₅	0.237
Nitrogen	0.500
Silicic acid	0.033
Insoluble matter	0.196

Undoubtedly lime in some form or other had been added to the "Refuse", as shown by the high ash and calcium content.

Protein. Numerous protein determinations (N x 6.25) by the Kjeldahl method showed an average of about 4 1/2 to 5 per cent. One sample gave as high as 0.964 per cent nitrogen, or 6.02 per cent protein on a dry matter basis. On this sample albuminoid and amido nitrogen was determined by the Stutzer method,¹ giving 0.678 (equivalent to 4.24) per cent albuminoid, and 0.286 (equivalent to 1.78) per cent amido nitrogen, respectively.

1 A.O.A.C. Bul. 107, p. 38.

Roughly speaking, about one-third of the total nitrogen was found to be in the amide form.

Fat. The ether extract was very small in quantity, usually about 1 per cent. It had the appearance of a heavy, light-colored oil and possessed a pleasant nutty odor.

Fiber. Fiber in all cases was fairly uniform in amount, being about 7 1/2 per cent of the dry matter. It was noticed while making the determinations that the vegetable ivory acted as an indicator, the change from light buff with acid to a deep wine color with alkali being quite abrupt. After boiling with the dilute alkali a peculiar aldehyde odor was always noticed, resembling that produced when hay is similarly treated. Both the residue from the fiber determinations and the original material were tested for the presence of lignin, but neither phloroglucinol nor aniline-sulphate produced any color reaction whatever.

Nitrogen-Free Extract.

(1) Mannan. It has long been known that the greater part of the carbohydrate material of vegetable ivory consists of mannose, or more accurately speaking, mannan, its anhydride condensation product. Mannan, $(C_6H_{10}O_5)_n$ is readily hydrolyzed to mannose by boiling with dilute acids, or is inverted by the action of a specific organism *seminase*.¹ According to Fischer and Hirschberger² the simplest method of obtaining the mannose is to heat one part of the vegetable ivory meal with two parts of 6 per cent HCl on the water bath for six hours with a return condenser. Then, after filtering and neutralizing, add an excess of phenylhydrazine acetate. Mannose-phenylhydrazone,

¹ Herissey - Compt. rend., 133, 49, 302.

² Ber., 22, 3218.

($C_6H_{12}O_5N - NH C_6H_5$), is formed, from which the hexose is later separated and crystallized. According to Tollens,¹ the separation is best carried out by mixing 5 parts of mannose-phenylhydrazone with 4 parts of benzaldehyde, 5 parts of water and 5 parts of alcohol, heating the whole on a water bath for half an hour with a return condenser, filtering out the insoluble benzaldehyde-hydrazone and evaporating the filtrate to a syrup. From the syrup mannose will crystallize out after being properly primed.

The isolation of mannose was carried out as outlined above with some variations. One hundred grams of vegetable ivory meal were digested on the water bath with reflex condenser for six hours with 200 c.c. of 6 per cent H Cl. The liquid was then filtered off and the residue washed and squeezed out dry. Filtrate and washings were then neutralized with NaOH and shaken out several times with carbon black. After the final filtration phenylhydrazine (dissolved in acetic acid) was added at the rate of .3 gram for every gram of ivory meal used.² The mannose-phenylhydrazone separated out, on standing twenty-four hours in the cold, as a heavy, fine grained, buff colored precipitate. This was washed with cold H_2O and dried in a vacuum at room temperature. Particles of this impure hydrazone when placed in a capillary tube and heated slowly in a H_2SO_4 bath, melted at $183^{\circ} C$.

A portion of the precipitate was purified by boiling a long time with a large volume of 95 per cent alcohol, filtering and again boiling with fresh alcohol until at the end of two days an almost snow white hydrazone resulted. This melted at $196^{\circ} C$.

1 Abderhalden's Biochem. Arbeitsmethoden. (1909), II, 74.

2 Bourquelot and Herissey, Compt. Rend. 129, p.p. 339 recommend a mixture of 1.2 parts phenylhydrazine, 1.2 parts glacial acetic acid and 6 parts H_2O , added for each part of actual mannose expected.

demonstrating unquestionably the existence of mannose or its polymer mannan in vegetable ivory.

Another portion, to which 16 grams of benzaldehyde, 20 grams of 95 per cent alcohol and 20 grams of water had been added, was digested on the water bath 30 minutes with a return condenser. Large, dark red, needlelike crystals of insoluble benzaldehyde-hydrazone soon formed and were removed by filtration. This filtrate, containing the liberated mannose was again treated with a little benzaldehyde and refiltered. It was then repeatedly shaken up with ether to remove the last traces of benzaldehyde, and after clarifying with carbon black, was evaporated in a vacuum oven at room temperature to a thick syrup. The syrup was taken up with absolute alcohol and evaporated several times to remove water. Finally it was set aside in a crystallizing dish, placed in a large desiccator and at the end of two weeks' time, microscopic crystals began to form. These gradually increased until practically all the syrup was crystallized. After drying on porous tile these crystals melted at 132°C .¹ A few cubic centimeters of the syrup primed with "Merck's" commercial mannose, crystallized in about 5 days. Repeated crystallization in both cases produced an almost pure white product having a very sweet and at the same time a rather bitter taste.

¹ Browne gives the melting point of mannose as being 132°C .; Van Nostrand as $132-3^{\circ}\text{C}$.

(3) Galactan.¹ Repeated attempts to produce mucic acid by oxidation with nitric acid proved futile. The exact method for the detection and determination of galactan was carried out always with negative results.

(4) Starch. Microscopic examination with iodine failed to give the slightest evidence of starch, either in the white fleshy part of the nut or in the brown outer coating.

(5) Dextran. Dextrose (or dextran) was shown to be absent in vegetable ivory by its inability to form saccharic acid. As a check on the method used, a sample of pure glucose was treated exactly as was the ivory meal. No difficulty was experienced in securing the saccharic acid from the check. The manipulation, according to Tollens and Gans,² was carried out as follows:-

Five grams of pulverized vegetable ivory meal and five grams of pure glucose were treated side by side in porcelain dishes with 30 c.c. each of 1.15 sp. gr. HNO_3 . These were warmed up in the steam bath with frequent stirrings until the acid had evaporated nearly to dryness and the red nitrous fumes had ceased to be given off. Each was then taken up with 30 c.c. of water and filtered. To each filtrate, while heated over an open flame, was added enough powdered K_2CO_3 to give an alkaline reaction to litmus paper. Then glacial acetic acid was added until a strong odor of acid was given off. Both liquors were then put into crystallizing dishes and set aside. In three hours' time the glucose dish showed a few small crystals, the vegetable ivory none. After forty-eight hours a large amount

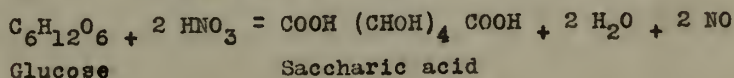
¹ A.O.A.C. Bul. 107, p. 55.

² Ber. 21, 2149.

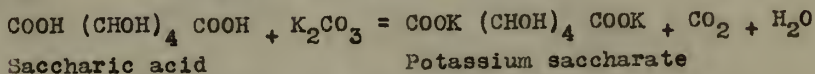
of small granular crystals had formed in the glucose liquor and a few needlelike crystals in the vegetable ivory liquor. These latter gave a strong test for nitrates with diphenylamine and when analyzed showed 13.71 per cent nitrogen and 38.47 per cent potassium, proving them to be nothing but potassium nitrate¹ formed by the excess HNO_3 in combination with the K_2CO_3 used to neutralize. The crystals in the glucose liquor were potassium saccharate as demonstrated by the formation of the silver salt as follows:- .25 grams of the crystals were dissolved in 50 c.c. of water and, after exactly neutralizing with a little dilute NH_4OH , were added to a cold solution of AgNO_3 (.4 gram in 50 c.c. H_2O). After standing two hours a heavy white precipitate had collected on the bottom of the beaker which was filtered through a tared porcelain Gooch, washed, dried and weighed. When ignited and reweighed, the remaining spongy silver was found to be 50.73 per cent of the amount of original silver salt. The theoretical amount of silver in silver saccharate is 50.91 per cent.

Reactions.

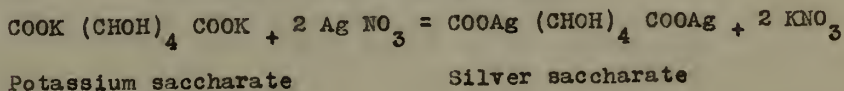
- (1) Oxidation of glucose to saccharic acid.



- (2) Formation of the potassium salt.



- (3) Formation of the silver salt.



¹ Theoretical percentage of nitrogen and potassium in KNO_3 equals 13.84 and 38.61 respectively.

(6) Alcoholic Precipitate. (Pectin?) It was found

by boiling a little of the vegetable ivory meal in water, filtering out the insoluble portion and then adding the clear filtrate to a large volume of strong alcohol, that a precipitate would form after standing some time. Since this process is similar to that employed in separating pectin (plant mucilage) from fruits, it was first supposed to be the same product. In fact in analyses of vegetable ivory reported by German chemists,¹ definite percentages of pectin are recorded. However, the precipitate in this case did not resemble those obtained from fruits, being at first simply a milky opalescence which later settled out as a somewhat flocculent white powder. It was not a gummy, sticky mass as is commonly obtained. This peculiarity led to further investigation. The actual amount present was first determined by boiling 2 gram charges of the finely pulverized ivory meal with 100 c.c. of water for thirty minutes, filtering through filter paper, and, after washing with 25 c.c. of water, concentrating the filtrate to 50 c.c. This was added with stirring to 500 c.c. of 95 per cent alcohol and allowed to stand twenty-four hours, at the end of which time the precipitate had collected at the bottom of the beaker and the supernatant liquid could be filtered off through a platinum Gooch. The precipitate was washed into the crucible with alcohol, and, after filtering, was dried two hours at 100° C., weighed, ignited and reweighed. The loss in weight was estimated as "Alcoholic Precipitate". Several repeated trials gave very close checks, the average being 2.78 per cent on a dry matter basis.

According to Browne,² pectin, supposed by many to be an

1 G. Loges and Reiss in Landw. Wochenblatt für Schleswig-Holstein
1886 p. 255 and 353.

2 p. 601.

oxygen or acid derivative of cellulose, is readily oxidized to mucic acid by proper treatment with nitric acid. The product from vegetable ivory meal when so treated produced no mucic acid. That it could not be of pentose character was demonstrated by running pentosan determinations on the filtered precipitate. Not the slightest trace of phloroglucid formed, showing the absence of five carbon sugars.

From various authorities and from actual observation, pectin derived from fruit is known to reduce Fehling's solution. To determine the reducing action of this material, definite amounts were dissolved in 100 c.c. of water and hydrolized in the cold (20-25° C.) with 10 c.c. of strong H Cl for twenty- four hours. After neutralizing, 50 c.c. aliquots were used to determine the amount of sugar present, or at least the amount of reduction, with negative results. Similar amounts were treated by boiling five hours with 1.125 sp. gr. H Cl after standing twenty-four hours. Indications of reduction were not noted.

On the supposition that the precipitate might be of a nitrogenous nature, .1115 gram was transferred to a Kjeldahl flask and a nitrogen determination made, with negative results.

In view of these facts it would seem that this particular alcoholic precipitate was not pectin, or, if it was pectin, that one can readily agree with Browne's statement¹ that, "The chemistry of the pectins is stillⁱⁿ/a very unsettled condition".

(7) Results of Sugar Determinations with Fehling's Solution. As far as is known no mention is made in literature of a method for the actual quantitative determination of mannose in impure mixtures or of mannose as present in vegetable ivory.

Bourquelot and Herissey, in a reference previously cited, seem to have worked out a method for quantitative precipitation with phenylhydrazine, but it is applicable to substances containing mannose only, - not to a mixture of several sugars.

In an attempt to get at a method for the direct estimation of mannose, a large number of determinations were made with Fehling's solution (Allihn's modification) of which the following is the result.

Water soluble sugar (so-called) was first determined without inversion by washing 3 grams of the finely ground material on a filter paper with 250 c.c. of water. Fifty c.c. aliquots of this solution were used and the average of six results on different samples was .5 of 1 per cent, calculated as invert sugar. It is possible that a very small part of the mannan or other substances contained in the meal may have been changed to a water soluble form capable of reducing Fehling's solution. The amount obtained was so small that it was impossible to determine this point. From results that follow, however, it would seem more probable that the .5 per cent represented invert sugar other than glucose.

Total sugars were next estimated by hydrolyzing 100 c.c. of the remainder of the above solutions with 10 c.c. of strong H Cl at 20° C. for twenty-four hours. The solutions were then neutralized, made to a volume of 200 c.c. and 50 c.c. aliquots used. A number of samples were tested with results ranging from 1.84 per cent to 2.37 per cent, calculated as invert sugar. About 2 per cent seems to be the fairest average.

Sugar by starch method. Evidently the mannose, or more properly speaking, the mannan existed as a hemi-cellulose, or the

total sugar would have been in an enormous excess of 2 per cent. The residues remaining on the filter papers from the previous determinations were washed with 200 c.c. of water into flasks containing 20 c.c. of 1.125 sp. gr. H Cl and allowed to stand twenty-four hours. They were then boiled two and one-half hours, cooled, neutralized, made to a volume of 1,000 c.c. and filtered. Twenty-five c.c. aliquots were used. The average of these tests, using Allihn's tables, were

49.40 per cent, calculated as invert sugar, or

47.40 " " " " dextrose.

When the same process was repeated with four hours' boiling instead of 2 and one-half hours, the following percentages were obtained:

67.52 per cent as invert sugar, or

65.00 " " " dextrose.

Noticing the increased amount due to prolonged boiling, the next step was to run a series of tests, boiling five, six, seven and eight hours respectively. The following table gives the actual weights of cuprus oxide obtained from 25 c.c. aliquots, using 1 gram of material made up to a volume of 500 c.c.

Table III.

Milligrams of Cu_2O in Sugar Aliquots.

<u>Time</u>	<u>5 hours</u>	<u>6 hours</u>	<u>7 hours</u>	<u>8 hours</u>
(a) Cu_2O	85.5	84.5	85.5	85.6
(b) Cu_2O	84.5	84.3	85.0	85.0
Average	85.0	84.4	85.3	85.3

These results show that there was no increase in the amount of sugar hydrolized after the fifth hour. In fact the operation was complete sometime between the fourth and fifth hour.

It was noticed in each case that the characteristic buff color of the acid solution (similar to that mentioned in connection with fiber determinations) bleached out after about four and one-half hours' boiling, so that the liquid became quite colorless. It occurred to the writer that the completion of hydrolysis and the disappearance of the color might be simultaneous, i.e., that the color might be dependent on the form of the sugar molecule before inversion. This point was not investigated.

The average of the eight determinations given above converted into terms of sugar gives

76.40 per cent as invert sugar, or

73.40 " " " dextrose.

These percentages include the previously obtained total and water soluble sugars from the water extract (about 2 per cent), since the trouble was not taken to previously wash the samples.

The moisture in these samples equalled 11.84 per cent, and the nitrogen-free extract from a previous fodder analysis was 85.16 per cent when calculated as dry matter. By converting the sugars to a dry matter basis, one secures

86.66 per cent as invert sugar, or

83.26 " " " dextrose.

If to these are added the 2.78 per cent of so-called pectin already obtained, the total percentage of carbohydrates becomes 89.44 and 86.04 respectively, each being slightly in excess of the 85.16 per cent extract matter.

It is readily seen that there are many undue assumptions in the foregoing work. Thus the mannose sugar is estimated by tables made for dextrose or invert sugar. Reasoning from the similarity of dextrose to mannose, the dextrose table seems to be

the more nearly applicable. The difference in the total nitrogen-free extract constituents when so calculated is less than 1 per cent larger than those determined in the fodder analysis. However, until a table for computing mannose itself has been made¹ it cannot be accurately said that so much reduced copper is equivalent to so much mannose. Furthermore, the presence of a small amount of pentose sugar has not been taken into account. Pentoses reduce Fehling's solution and there is no doubt that all the pentosan material was hydrolyzed during the above process, but that it should reduce at the same rate as mannose is improbable. Again since actual dextrose (dextran) has been shown to be absent, an error is introduced when the 2 per cent of so-called "Total Sugar" is so estimated. It would seem, however, that for approximate work the use of prolonged acid hydrolysis and Fehling's solution is as satisfactory a method of estimating mannose in vegetable ivory as any, since some of its errors offset others and the total error is not great.

Summary of Chemical Work.

1. Aside from the general composition, fodder analyses show that the most striking features about vegetable ivory meal are the low protein content, of which one-third is in the amido form, and the extremely large proportion (about 75 per cent) of carbohydrate exclusive of crude fiber.

2. The presence of mannan is demonstrated by the formation of a hydrazone with phenylhydrazine which in the crude form melts at 183° C. and when purified at 196° C. Mannose can be isolated

1 No table for estimating mannose by Fehling's solution has been found by the writer.

either by separating the hydrxzone with benzaldehyde and crystallizing the hexose from absolute alcohol, or by similarly treating the neutral liquor after hydrolysis. The crystallization can be hastened by inoculation. These crystals melt at 132° C.

3. Pentosan is found to be present to the extent of some 2.43 per cent of the dry matter.

4. Neither galactan, starch nor lignin are contained in vegetable ivory meal.

5. Dextran is shown to be absent by the inability to produce saccharic acid.

6. The alcoholic precipitate, present to the extent of about $2\frac{1}{2}$ per cent, differs from fruit pectin in that it does not form mucic acid, and does not reduce copper. It does not contain nitrogen and is not of a pentose character.

7. Experiments with Fehling's solution show (a) that about $1\frac{1}{2}$ per cent of water soluble reducing material, presumably invert sugar, is present; (b) that about 2 per cent of so-called total sugars are present; (c) that at least four and one-half hours of actual boiling of acid solution is necessary to complete the hydrolysis of the mannan; and (d) that calculated as dextrose about 83 per cent of the dry matter is carbohydrate, largely mannan

The work with Fehling's solution further shows that an approximate estimation of mannose in vegetable ivory meal may be made with ease and comparative rapidity by its use. The accuracy of the method is limited by several unavoidable complications, but the sum of the carbohydrates, other than crude fiber, when estimated by it, corresponds within less than 1 per cent to the sum as calculated by fodder analyses.

8. All but approximately 7.5 per cent of the nitrogen-free extract is mannan, that 7.5 per cent being composed of about 2.5 per cent pentosan, 2.5 per cent "Pectin (so-called), 2 per cent total sugars and .5 per cent invert sugar.

Digestion Experiment A.

The determination of digestibility was carried out with sheep in the usual manner.¹ The daily feedings and collections of manure samples were made by Mr. J. R. Alcock, the regular employee at the feeding barn. Two sheep were fed a ration consisting of 500 grams of English hay, 150 grams of gluten feed, 200 grams of finely ground vegetable ivory meal and 10 grams of salt with water ad libitum. Rations for the entire test were weighed out at the beginning and samples sent to the laboratory and immediately analyzed.

Table I.

Composition of Feedstuffs (Per cent).

<u>Moisture Table.</u>			
<u>Feed</u>	<u>Hay</u>	<u>Gluten</u>	<u>Vegetable Ivory Meal</u>
Moisture	11.95	10.07	12.64
Dry matter	<u>88.05</u>	<u>89.93</u>	<u>87.36</u>
Total	100.00	100.00	100.00
<u>Dry Matter Table.</u>			
Ash	5.81	1.11	1.37
Protein	9.34	26.96	6.02
Fat	2.88	3.94	0.67
Fiber	31.70	8.70	7.02
Nitrogen-free extract	<u>50.78</u>	<u>59.29</u>	<u>84.90</u>
Total	100.00	100.00	100.00

The experiment lasted fourteen days, seven of which were preliminary, and during that time no disturbances in digestion

1 For details of the methods used in digestion work see the 11th Annual Report of Mass. Exp. Sta. (1893).

were observed. The sheep ate the vegetable ivory mixture readily.

One-tenth of the daily manure excreted by each sheep was carefully dried and preserved. Later these tenths were composited and analyzed.

Table II.

Daily Amounts of Manure and Urine Excreted and Water Consumed.

<u>Date</u>	<u>Manure (Grams)</u>	<u>One-tenth Preserved</u>	<u>Sheep V.</u>		<u>Urine¹ (c.c.)</u>
			<u>Air Dry</u>	<u>Water Consumed (c.c.)</u>	
Nov. 16	711	71.1	29.25	2300	2151
" 17	626	62.6	28.20	1825	975
" 18	684	68.4	28.63	2170	1397
" 19	476	47.6	21.20	1935	2201
" 20	476	47.6	20.45	2225	1135
" 21	536	53.6	23.37	2100	1459
" 22	615	61.5	25.37	1785	914
Average	589	58.9	25.21	2049	1461

Sheep VI.

Nov. 16	535	53.5	25.21	350	621
" 17	527	52.7	25.45	350	665
" 18	495	49.5	23.21	2220	681
" 19	483	48.3	23.39	350	547
" 20	545	54.5	25.89	2245	643
" 21	407	40.7	19.93	2230	543
" 22	512	51.2	26.28	350	647
Average	507	50.7	24.19	1156	621

Table III.

Composition of Feces (Per Cent)

Moisture Table.

	<u>Sheep V</u>	<u>Sheep VI</u>
Moisture	5.70	5.50
Dry Matter	<u>94.30</u>	<u>94.50</u>
Total	100.00	100.00

¹ The amount of urine in each case was increased by 100 c.c. of carbolic disinfectant and wash water used at the barn.

Dry Matter Table.

	<u>Sheep V</u>	<u>Sheep VI</u>
Ash	9.16	9.80
Protein	15.60	14.70
Fat	3.96	3.44
Fiber	25.96	25.34
Nitrogen-free extract	<u>45.32</u>	<u>46.72</u>
Total	100.00	100.00

The sheep were weighed on the first two and the last two days of the digestion period and the averages taken to determine gain or loss in body weight.

Table IV.Gain or Loss in Weight (Pounds)

	<u>Beginning</u>	<u>End</u>	<u>Gain</u>	<u>Loss</u>
Sheep V	139.25	137.25	--	2.00
Sheep VI	160.13	163.83	3.70	--

By applying the analyses in Table I to the total rations fed, the total amounts of dry matter and food constituents are obtained, from which the amount of dry matter and the amounts of the several constituents of the manure are subtracted. The remainder is the amount of hay, gluten and vegetable ivory meal digested in pounds. Subtracting from this the amount of hay and gluten digested¹ the amount of vegetable ivory digested is secured. Dividing the amount digested by the amount fed, gives the percentages of the several constituents digested.

1 Obtained by applying the digestion coefficient of hay and gluten alone to the amounts fed.

Table V.Digestibility Coefficients (Grams.)Sheep V.

	Dry Matter	Protein	Fat	Fiber	Ash	Nitrogen- Free Extract
550 gr. English hay	484.28	45.67	11.04	153.52	28.14	245.91
150 " gluten feed	134.90	36.37	5.32	11.74	1.50	79.97
200 " veg. ivory	174.72	10.52	1.21	12.27	2.39	148.33
Amount consumed	793.90	92.56	17.57	177.53	32.03	474.21
Minus 252.10 gr. manure	237.73	37.09	9.41	61.71	21.78	107.74
Hay, gluten and ivory digested	556.17	55.47	8.16	115.82	10.25	366.47
Minus hay and gluten digested	408.66	55.79	9.16	109.07	9.19	228.12
Vegetable ivory digested	147.51	--	--	6.75	1.06	138.35
Percent digested	84.43	--	--	55.01	44.35	93.27

Sheep VI.

Amount consumed as above	793.90	92.56	17.57	177.53	32.03	474.21
Minus 241.94 gr. manure	228.63	33.61	7.86	57.93	22.41	106.82
Hay, gluten and ivory digested	565.27	58.95	9.71	119.60	9.62	367.39
Minus hay and gluten digested	408.66	55.79	9.16	109.07	9.19	228.12
Vegetable ivory digested	156.61	3.16	0.55	10.53	0.43	139.27
Percent digested	89.63	30.04	45.45	85.82	17.99	93.89
Average Per Cent both sheep	87.03	30.04 ¹	45.45 ¹	70.42	31.17	93.58

1 One sheep only.

	Dry Matter	Protein	Fat	Fiber	Ash	Nitrogen- Free Extract
Percentage Digesti- bility of English hay and gluten previously deter- mined ¹	66	68	56	66	31	70

Table V shows that the two digestion trials for nitrogen-free extract agree very closely. It is to be noted further that this extract matter constituted about 85 per cent of the total dry matter of the ivory meal, and that it had a digestibility of 94 per cent. In the case of the fat and ash the results are uncertain, but this is not surprising because so very little of these two ingredients is present. The digestibility of the fiber is not very satisfactory, and the same may be said of the protein. The percentages of these two ingredients, however, in the ivory meal are relatively small.

Table VI.

Comparison of Vegetable Ivory and Corn Meal Coefficients.

	Dry Matter	Protein	Fat	Fiber	Nitrogen- Free Extract
Vegetable ivory	87	30	45	70	94
Corn meal ²	88	67	90	--	92

Of these figures the first and last columns demand the most attention. Corn meal contains nearly as much nitrogen-free extract as the vegetable ivory, and it would appear that the digestibility of each is approximately the same.

As a supplementary check on the metabolism of the sheep the urine was daily collected, weighed and sampled, and nitrogen

1 Obtained from previous digestion experiments similar to the one under discussion in which a part of the same lot of hay and gluten feed was used.
2 Dr. J. R. Lindsay's Compilation. 23rd Annual Report, Mass. Exp. Sta.

determined. A study of Table VII shows that Sheep V excreted more nitrogen than was supplied in its food. This sheep lost in weight. Sheep VI, however, gained in body weight and it will be noted that less nitrogen was given off than was consumed.

Table VII.

Nitrogen Balance.

(Estimated in grams of protein)

	Consumed	Excreted	Gain or Loss.
Sheep V	647.92	659.07	-11.15 grams.
Sheep VI	647.92	599.46	+48.46 "

As previously stated, the animals showed no adverse conditions during the experiment. The fact that one sheep gained slightly while the other lost was probably due to irritability rather than to improper feeding. The vegetable ivory meal mixed with other grains was readily eaten and proved highly digestible.

Note: A more recent experiment conducted by Dr. J. B. Lindsey with three sheep and a different sample of ivory meal, gave the following coefficients, to which are appended the writer's results for comparison.

Comparison of Digestion Coefficients.						
Vegetable Ivory	Number of Sheep	Dry Matter	Protein	Fat	Fiber	Nitrogen-Free Extract
Lindsey	3	81	41 ¹	56	73	89
Beals	2	87	30	45 ²	70	94
Average		84	36	51	72	92

Applying the average coefficients to the composition of the dry matter of the ivory meal³ and the average coefficients for corn meal to the dry matter contained in the latter⁴ and multiplying by 2000, one secures the following amounts of digestible matter in 1 ton of each of the two feeds.

Pounds of Digestible Nutrients in Vegetable Ivory and Corn Meals Per Ton					
Feed	Protein	Fat	Fiber	Nitrogen-Free Extract	Total
Vegetable ivory	42.34	6.83	101.08	1,582.20	1,732.45
Corn meal	147.52	78.84	--	1,486.40	1,712.76

On the basis of digestible organic matter the results indicate that the ivory meal is equal in feeding value to corn meal. Unfortunately it is impossible to estimate by means of digestion experiments the amount of energy required to chew and digest different feedstuffs. In view of the excess of fiber in the ivory meal over that of the corn meal (7 per cent in ivory meal vs. 2 per cent in corn meal), of the tough horny nature of the ivory nut, and of the uncertainty of the nutritive value of the mannan as compared with starch, one is justified in assuming that the ivory meal cannot have as high a nutritive effect as has the corn meal.

1 Different sheep showed variable results.

2 One sheep only.

3 See page 21.

4 The average composition of corn meal on dry matter basis per Dr. J. B. Lindsey's compilations, is protein 11.01%, fat 4.38%, fiber 2.25% and nitrogen-free extract 80.79%.

Digestion Experiment B.

As another means of determining how completely vegetable ivory meal was digested, a second experiment was instituted feeding the same amounts of the several foods as in the first experiment. The basal ration consisted of hay and gluten feed, and the ration proper of the same foods in like amounts, plus 200 grams of vegetable ivory meal. Each ration was fed for fourteen consecutive days, the feces being collected for the last seven days in each period, and aliquots preserved. In this experiment the hay, gluten feed and ivory meal ration preceded the basal ration of hay and gluten feed. The feces were tested for total sugar after acid hydrolysis, to note if the percentage of sugar was higher in the ivory meal period than in the period without the meal. It is understood that little or no sugar should appear, as such, in healthy feces, representing thorough digestion, and the relatively large amounts which are reported below are accounted for by the hydrolysis of pentosans and other hemi-celluloses, largely from the hay. It was necessary to hydrolyze with strong acid and boiling in order to include completely the sugar of the vegetable ivory,¹ if any, which might have passed through the animal unchanged.

Method and Data. The air dry samples of the feces from Sheep IV, V and VI were carefully sub-sampled and ground, (3 gram duplicate portions of each) for each period, were then weighed out and placed in 200 c.c. of water with 20 c.c. of 1.125 sp. gr. H Cl. After standing twenty-four hours at 20° C. they were boiled five hours with a return condenser. When cold they were neutralized,

¹ See results of sugar work in chemical section.

made to a volume of 500 c.c. and filtered, 50 c.c. aliquots being used for the determinations.

Table I.

Sugar Determinations (in mg. Cu₂ O)

Ration I. Hay, Gluten Feed and Vegetable Ivory.

	<u>Sheep IV</u>	<u>Sheep V</u>	<u>Sheep VI</u>
(a)	.1678	.1620	.1596
(b)	.1688	.1645	.1626

Ration II. Hay and Gluten Feed Only.

(a)	.1688	.1600	.1550
(b)	.1660	.1560	.1590

Moisture on these respective samples ran as follows:

Table II.

Ration I. Hay, Gluten Feed and Vegetable Ivory.

<u>Sheep IV</u>	<u>Sheep V</u>	<u>Sheep VI</u>
5.45%	5.64%	5.82%

Ration II. Hay and Gluten Feed Only.

5.16%	5.12%	4.86%
-------	-------	-------

Calculating on a dry matter basis it was found that the average carbohydrate content for the feces of the first period was 25.46 per cent and that of the second period 24.68 per cent. In other words, the total amount of carbohydrate, so-called found in the feces when vegetable ivory had been included in the ration was only .78 per cent more than was found when it had not been included. This is relatively such a small amount that

it seems safe to conclude that very little, if any, of the carbohydrate of the vegetable ivory escaped undigested. Presumably that which did escape was estimated with the crude fiber rather than with the nitrogen-free extract. The mannan therefore appears to have been quite thoroughly hydrolyzed and assimilated by the sheep, and one has a right to assume that it was made use of by the animal organism in the same way as dextrose.

Feeding Experiment A.

During March, April and May, 1914, an experiment to compare the relative feeding value of vegetable ivory meal and corn meal was carried out as follows:

Three pairs of cows were fed for periods of five weeks each on rations consisting of substantially 2.5 pounds of wheat bran, 2.5 pounds of cottonseed meal and what hay the animals would eat clean (about 20 pounds). Three pounds of vegetable ivory meal or three pounds of corn meal were fed in addition. The experiment was conducted on the reversal plan, i. e., feeding one cow of each pair the basal ration, plus the vegetable ivory for five weeks, while the mate received corn meal, and then vice versa for the five weeks. In this way one would be able to note the comparison of like amounts of the two materials on milk production and body weight.

In a preliminary trial one cow, Samantha, refused to eat the ration containing the vegetable ivory and Samantha II was substituted in her place.

Daily samples of the grain and ivory meal were taken and preserved in glass stoppered bottles. These were brought to the laboratory for analysis at the end of each half of the trial. The hay also was sampled three times during each half of the trial and determinations of moisture made and aliquots preserved for analysis.

Milk samples were taken for five consecutive days in the first, third and fourth weeks of each half of the experiment. The week's composite was brought to the laboratory for the determination of fat and total solids.

The cows were weighed on two consecutive days at the beginning and end of each half of the experiment and careful records kept.

Table I.

History of Cows.

Cow	Breed	Age	Yield of Milk
			at Beginning of Trial (Pounds)
Samantha II	G. Holstein	5	34
Fancy III	G. Jersey	5	32
Betty	G. Jersey	10	22
Betty II	G. Ayrshire	7	25
Amy	P. Jersey	6	24
Amy II	P. Jersey	4	20

Table II.

Gain or Loss in Herd Weight (Pounds)

<u>Ration</u>	<u>Herd</u>		<u>Average per Cow</u>	
	<u>Gain</u>	<u>Loss</u>	<u>Gain</u>	<u>Loss</u>
Corn Meal	94	0	15.6	0
Vegetable ivory	6	0	1.	0

At the completion of the experiment a distinct gain in herd weight was noticed when the corn meal ration was fed over that of the vegetable ivory ration.

Table III.Composition of Materials Fed (Per Cent)

<u>Moisture Table</u>	<u>Hay</u>	<u>Cottonseed Meal</u>	<u>Wheat Bran</u>	<u>Corn Meal</u>	<u>Vegetable Ivory</u>
Moisture	10.38	7.98	11.88	12.66	11.84
Dry Matter	<u>89.62</u>	<u>92.02</u>	<u>88.12</u>	<u>87.34</u>	<u>88.16</u>
Total	100.00	100.00	100.00	100.00	100.00

<u>Dry Matter Table</u>	<u>Hay</u>	<u>Cottonseed Meal</u>	<u>Wheat Bran</u>	<u>Corn Meal</u>	<u>Vegetable Ivory</u>
Ash	6.67	6.35	7.15	1.45	0.93
Protein	9.41	41.21	17.43	10.54	4.40
Fat	2.34	7.22	5.61	4.42	1.10
Fiber	33.08	14.35	10.78	2.07	8.41
Nitrogen-free extract	<u>48.50</u>	<u>30.87</u>	<u>59.03</u>	<u>81.52</u>	<u>85.16</u>
Total	100.00	100.00	100.00	100.00	100.00

The coefficients given in the following table were taken from station publications of previous digestion experiments, with the exception of those for vegetable ivory, which are the results of the experiment given in Digestion Experiment A.

Table IV.Digestion Coefficients of Materials Fed.

	<u>Hay</u>	<u>Cottonseed Meal</u>	<u>Wheat Bran</u>	<u>Corn Meal</u>	<u>Vegetable Ivory</u>
Dry matter	55	79	66	88	87
Protein	47	84	77	67	30
Fat	45	94	63	90	45
Fiber	65	35	39	--	70
Nitrogen-free extract	59	78	71	92	94

Table V.

Duration of Experiment and Daily Ration (pounds)												
Cows	Time (Days)	Ration (1st half)					Ration (2nd half)					
		Hay	C.S. Meal	Bran	Corn Meal	Veg. Ivory	Hay	C.S. Meal	Bran	Corn Meal	Veg. Ivory	
1st Pair Samantha II	35	24	2½	3	1	3	24	2½	3	4	-	
Fancy III	35	20	2½	2½	4	-	20	2½	2½	1	3	
2nd Pair Betty	35	(1) 20	2	2	-	3	20	2	2	3	-	
Betty II	35	(21) 21	2½	2½	3	-	21	2½	2½	-	3	
Amy	28	(8½) 20	2	2	3	-	(34½) 20	2	2	-	3	
3rd Pair Amy II	28	(15½) 19	2	2	-	3	(20½) 19	2	2	3	-	

The above table shows the length of time each pair of cows was fed each ration and the daily ration fed to each cow. The daily requirements for maintenance and milk were carefully worked out beforehand.¹ The third pair, Amy and Amy II, was allowed only four weeks instead of five due to their extended period of lactation. Figures in parenthesis under HAY column represent the number of pounds of hay unconsumed during the entire period.

By multiplying the amounts of the daily ration by 196, the total number of days, the total amount consumed in each ration is obtained.

Table VI.

Total Amount Consumed in Each Ration (pounds)

Ration	Hay	C. S. Meal	Bran	Corn Meal	Vegetable Ivory
Corn meal	4034	444.5	462	658	--
Vegetable ivory	4012	444.5	462	70	588

¹ Manner of calculating rations is given in detail in Feeding Experiment C.

Dividing the totals consumed by the total days gives the average daily amount consumed per cow.

Table VII.

Ration	Average Daily Amount Consumed (Pounds).				
	Hay	C. S. Meal	Bran	Corn Meal	Vegetable Ivory
Corn meal	20.58	2.28	2.36	3.36	--
Vegetable ivory	20.46	2.28	2.36	1 ¹	3

By applying the digestion coefficients in Table IV to Table VII, the average number of pounds of digestible organic nutrients received daily per cow was determined.

Table VIII.

Ration	Pounds of Digestible Organic Nutrients in Daily Ration.					
	Protein	Fat	Fiber	Nitrogen- Free Extract	Total	Nutritive Ratio
Corn meal	2.03	0.53	4.07	8.86	15.47	1 : 6.9
Vegetable ivory	1.88	0.43	4.29	9.17	15.77	1 : 7.6

It will be noticed here that the total digestible carbohydrates is slightly greater for vegetable ivory than for corn meal. On the other hand protein and fat show a favorable balance for the corn meal.

Table IX.

Total Yield of Milk and Milk Ingredients.

Cows	Time (Weeks)	Corn Meal Ration.					
		Milk (lbs.)	Solids (%)	Solids (lbs.)	Fat (%)	Fat (lbs.)	Butter ¹ (lbs.)
Samantha II	5	1184.6	12.57	148.9	4.03	47.7	54.9
Fancy III	5	1131.8	12.90	146.0	4.33	49.0	57.2
Betty	5	761.6	13.76	104.8	4.77	36.3	42.3
Betty II	5	933.4	13.76	128.8	4.75	44.3	51.7
Amy	4	673.8	13.45	90.6	4.68	31.5	36.7
Amy II	4	558.3	14.75	82.3	5.45	30.4	35.5
Total	28	5243.5	13.37 ²	701.0	4.56 ³	239.2	278.3

Vegetable Ivory Ration.							
Samantha II	5	1200.6	12.70	652.5	4.13	49.6	57.9
Fancy III	5	1001.6	13.01	130.3	4.53	45.4	53.0
Betty	5	805.0	13.80	111.1	4.93	39.7	46.3
Betty II	5	897.6	13.61	122.2	4.49	40.3	47.0
Amy	4	620.7	13.26	82.3	4.74	29.4	34.8
Amy II	4	547.2	15.15	82.9	5.79	31.7	37.0
Total	28	5072.7	13.43 ²	681.3	4.65 ³	236.1	276.2

One hundred and seventy pounds more milk were produced by the corn meal ration than by the vegetable ivory ration. This excess is not pronounced, and while it is possible that the difference may be within the limit of experimental error, when taken together with the fact that the corn meal ration increased the live weight of the cows, it indicates at least that the corn meal was somewhat superior

¹ Butter equals butter fat plus $1/6$.

² Averages obtained by dividing total pounds of solids by total pounds of milk.

³ Averages obtained by dividing total pounds of fat by total pounds of milk.

to the vegetable ivory meal as a source of nutrition.

The average percentages of total solids and fat produced by each ration agree very closely, only a slightly larger proportion of each being produced by the vegetable ivory ration.

Table X.

Average Composition of Herd Milk on Each Ration.

<u>Ration</u>	<u>Total Solids (%)</u>	<u>Fat (%)</u>	<u>Solids not Fat (%)</u>
Corn meal	13.37	4.56	8.81
Vegetable ivory	13.43	4.65	8.74

For comparison the amounts of dry and digestible matter required to produce 100 pounds of milk, 1 pound of solids and 1 pound of fat have been tabulated. Slightly less of the corn meal ration was required than of the vegetable ivory to produce the definite amounts of milk and milk ingredients.

Table XI.

Dry and Digestible Matter Required to Produce Milk;

and Milk Ingredients.

<u>Ration</u>	<u>Dry Matter</u>			<u>Digestible Matter</u>		
	<u>100 lbs. Milk</u>	<u>1 lb. Solids</u>	<u>1 lb. Fat</u>	<u>100 lbs. Milk</u>	<u>1 lb. Solids</u>	<u>1 lb. Fat</u>
Corn meal	95.4	7.14	20.9	58.9	4.5	13.1
Vegetable ivory	98.4	7.33	21.1	60.6	4.5	13.0

This experiment indicates that ivory meal possesses a distinct feeding value, and that while somewhat inferior to corn meal the difference is not marked.

Judging from the greater difficulty met with in hydrolyzing the carbohydrate of the vegetable ivory¹ than the carbohydrate of

¹ See chemical section.

other feeding materials would it not be reasonable to suppose that the same relation would hold true in the digestive processes of animals? If this were the case, more of the total energy of the material would be used up in digestion and assimilation, which otherwise might be used for milk production. This would help to explain the failure of vegetable ivory to equal corn meal in productivity.

Another question naturally arises as to whether the basal ration of hay, bran and cottonseed meal, considering the somewhat advanced period of lactation of some of the cows, was not nearly sufficient for their needs, so that the corn or ivory meal was without pronounced effect. In other words, if the basal ration had been somewhat less would the difference between the corn meal and the ivory meal ration have been more pronounced? Other experiments will be necessary in order to fully answer these questions.

Feeding Experiment B.

A short experiment with three cows, supplementary to Experiment A, was carried out during January and February of 1915. A basal ration somewhat below what the cows needed for maintenance and milk¹ was fed for two weeks. Then the cows were given three pounds of vegetable ivory meal in addition for two weeks. The fifth and sixth weeks the cows were again given only the basal ration. The aim was to see if the animals would show any increase in weight or milk production in response to the addition of the ivory meal.

Table I.History of the Cows.

<u>Cows</u>	<u>Calved</u>	<u>Served</u>	<u>Age</u>
Red III	Aug. 11	Nov. 2	9
Betty III	Oct. 10	Dec. 3	2
Amy	Dec. 25	Feb. 9	7

Table II.Duration of the Experiment.

<u>Date (1915)</u>	<u>Ration</u>	<u>Pounds Vegetable Ivory Meal</u>
Jan. 13 - Jan. 26	Basal	0
Jan. 27 - Feb. 9	Vegetable ivory	3
Feb. 13 - Feb. 27	Basal	0

Table III.Basal Ration (pounds)

<u>Cows</u>	<u>Hay</u>	<u>Wheat Bran</u>	<u>Cottonseed Meal</u>	<u>Hominy</u>
Amy	18	2	2	1
Betty III	18	2	2	1
Red III	20	3	2	1

¹ Estimated from the amounts of digestible matter the animals had been regularly receiving.

The amount and quality of the milk was determined for the second week of each section of the experiment. Samples were taken in the usual way and the animals were weighed on two consecutive days at the beginning and end of each second week. These results were averaged to show gain or loss.

Table IV.

Weight of Cows (Pounds).

<u>Cows</u>	<u>1st Period (Basal)</u>	<u>2nd Period (Vegetable Ivory Meal)</u>	<u>3rd Period (Basal)</u>
Amy	800	787	770
Betty III	672	678	678
Red III	927	932	934

Little can be said about body weight as the addition of the vegetable ivory meal in the second period shows little or no resulting increase. The following table, however, shows an increase in the amount of milk produced during the first basal period. The return to the basal ration in the third period shows a decrease of 20.2 pounds, or 4.2 per cent, of the amount produced on the vegetable ivory meal ration.

Table V.

Pounds of Milk and Milk Ingredients.

<u>Cows</u>	<u>Basal Ration. Jan. 20-26</u>				
	<u>Milk</u>	<u>% Fat</u>	<u>Fat</u>	<u>% Solids</u>	<u>Solids</u>
Amy	196.5	5.50	10.81	13.77	27.06
Betty III	137.6	4.70	6.47	13.23	18.20
Red III	121.9	5.38	6.56	13.86	16.90
Total	456.0	5.22 ¹	23.84	13.63 ¹	62.16

1 Averages obtained by dividing the total pounds of fat or solids by the total pounds of milk.

Vegetable Ivory Meal Ration.
Feb. 3-9

<u>Cows</u>	<u>Milk</u>	<u>% Fat</u>	<u>Fat</u>	<u>% Solids</u>	<u>Solids</u>
Amy	199.2	4.90	9.76	13.14	26.17
Betty III	158.0	4.58	7.24	13.25	20.94
Red III	125.1	5.28	6.61	13.71	17.15
Total	482.3	4.90 ¹	23.61	13.30 ¹	64.26

Basal Ration. Feb. 21-27.

Amy	190.3	4.80	9.13	13.12	24.97
Betty III	146.4	4.60	6.73	13.31	19.49
Red III	125.4	5.38	6.75	13.93	17.47
Total	462.1	4.89 ¹	22.61	13.21 ¹	61.93

Though of short duration the experiment shows the favorable effects of the addition of three pounds per cow daily of the ivory meal to the basal ration. This addition increased the milk flow 5.7 per cent, and its removal caused a decrease of 4.2 per cent.

¹ Averages obtained by dividing the total pounds of fat or solids by the total pounds of milk.

Feeding Experiment C.

In Experiment A a definite amount of vegetable ivory meal was compared with an equal amount of corn meal. In order to more fully demonstrate the effect of the vegetable ivory, a herd of six cows was put on a basal ration of hay, bran, cottonseed meal and hominy meal for four weeks. Three of these six received in addition a quantity of the ivory meal, while it was withheld from the others. At the end of that period, which will be known as the first half of the experiment, conditions were reversed and during the four weeks of the second half the first three cows went without the vegetable ivory while the others received it. By this means any positive effect the ivory meal might have on body weight or milk production could be noticed, while the duration of the experiment was long enough to offset minor disturbing influences.

With the exception of one cow the animals remained in good health throughout the experiment, eating both rations with apparent relish. Cow Ida II had a bad attack of scours April 16 - 18 and Betty at times left parts of her food uneaten. Each cow was weighed before watering and feeding on two consecutive days at the beginning and end of each half of the trial. Samples of hay were taken at the beginning, middle and end of each half, while the grains were sampled daily. The milk of each cow was sampled in the usual manner on the first, third and fourth week of each half.

Table I.History of the Cows.(First Half)

<u>Name</u>	<u>Breed</u>	<u>Age</u>	<u>Last Calf</u>	<u>Served</u>	<u>Milk at Beginning of Trial (Pounds)</u>
Fancy III	G. Jersey	6	Jan. 22	--	38
Betty III	G. Ayrshire	2	Oct. 10	Dec. 3	21
Ida II	P. Jersey	2	Jan. 27	Feb. 20	23

(Second Half)

Betty	G. Jersey	11	Jan. 21	Feb. 28	30
Red III	G. Jersey	9	Aug. 11	Nov. 2	18
Amy	P. Jersey	7	Dec. 25	Feb. 19	27

Table II.Duration of the Experiment.(First Half)

<u>Date, 1915</u>	<u>Plus Ivory Cows</u>	<u>Minus Ivory Cows</u>	<u>Time</u>
Mar. 17 - Apr. 13	Fancy III	Betty	4 weeks
" " " "	Betty III	Red III	" "
" " " "	Ida II	Amy	" "

(Second Half)

Apr. 24 - May 21	Betty	Fancy III	4 weeks
" " " "	Red III	Betty III	" "
" " " "	Amy	Ida II	" "

The cows were selected so that one group as nearly as possible balanced the other in milk production, disposition and food consumption.

Before starting the experiment the individual rations were carefully calculated by the Haecker Standard¹ for maintenance and

1 T. L. Haecker, Minn. Bul. 130.

milk production, with a view toward avoiding excessive feeding. Thus the increase in milk due to the ivory meal, if any, would be more truly representative.

Tables following show the daily ration for each cow and the digestible nutrients in the ration as calculated from analyses, compared with those computed by the Haecker method. This latter method briefly consists of multiplying the live weight of the animal (in cwt.) by .07 for protein, .7 for carbohydrates and .01 for fat content. These figures give the pounds of digestible nutrients required for maintenance of the cow in question, and to them must be added the amounts which are required to produce the quantity and quality of milk the animal may be producing. This is calculated by applying Haecker's factors for 1 pound of milk of the given fat content to the number of pounds of milk the cow is daily producing.

For example, cow Fancy III weighed 8.85 cwt. at the beginning of the experiment and was giving 38.5 pounds of milk daily, which tested 4.58 per cent fat. According to Haecker then the following would represent the amounts of digestible nutrients required daily by this cow.

Table III.

<u>Constituent.</u>	<u>Protein.</u>	<u>Carbohydrate.</u>	<u>Fat.</u>
Body weight	8.85 cwt.	8.85 cwt.	8.85 cwt.
Factor	.07	0.7	.01
Maintenance requirement (Pounds)	.6195	6.1950	.0885
Pounds of milk	38.5	38.5	38.5
Factor for 1 pound of milk, 4.58% fat	.0516	.257	.0181
Milk requirement (Pounds)	1.9866	9.8945	.6969
To which add mainten- ance requirement as above	.6195	6.1950	.0885
Total requirement	2.6061	16.0895	.7854 = 19.4810

About 19.5 pounds of digestible nutrients then were needed daily by Fancy III to keep her in good bodily condition and allow her to maintain her average output of milk.

Next the amount of hay and grain necessary to supply approximately 19.5 pounds of digestible nutrients was calculated by applying the digestive coefficients¹ to their respective analyses.² In this way it was found that 20 pounds of hay, 3 pounds of wheat bran, 3 pounds of cottonseed meal and 3 pounds of vegetable ivory meal gave a total of 17.69 pounds of digestible nutrients with a nutritive ratio of 1 : 7.4. This was somewhat lower than the amount estimated by the Haecker method and was increased by 2 pounds of hay, making a total of 18.40 pounds of digestible nutrients. In a similar manner the ratios for the other cows were calculated, making occasional variations for breed or individual peculiarities.

Table IV.

Daily Rations (Pounds).

First Half (Mar. 17 - Apr. 13).

<u>Cows</u>	<u>Hay</u>	<u>Wheat Bran</u>	<u>Cottonseed Meal</u>	<u>Hominy</u>	<u>Vegetable Ivory Meal</u>
Fancy III	22	3	3	2	3
Betty III	16	2	2	1	3
Ida II	16	2	2	2	2½
Betty	20	3	2½	1½	-
Red III	18	2	2	1	-
Amy	19	2	2	2	-

¹ Previously determined.

² " " "

Second Half (Apr. 24 - May 21)

<u>Cows</u>	<u>Hay</u>	<u>Wheat Bran</u>	<u>Cottonseed Meal</u>	<u>Hominy</u>	<u>Vegetable Ivory Meal</u>
Fancy III	22	3	3	2	-
Betty III	16	2	2	1	-
Ida II	16	2	2	2	-
Betty	20	3	2½	1½	3
Red III	18	2	2	1	3
Amy	19	2	2	2	2½

Digestible nutrients in the ration calculated by analyses and digestion coefficients correspond as follows to the Haecker Standard.

Table V.First Half.

<u>Cows</u>	<u>Protein</u>		<u>Carbohydrate</u>		<u>Fat</u>		<u>Total</u>	
	<u>Ration</u>	<u>Haecker</u>	<u>Ration</u>	<u>Haecker</u>	<u>Ration</u>	<u>Haecker</u>	<u>Ration</u>	<u>Haecker</u>
Fancy III	2.52	2.61	15.13	16.09	.66	.79	18.40	19.49
Betty III	1.73	1.57	11.24	10.24	.51	.45	13.48	12.27
Ida II	1.80	1.74	11.45	11.18	.58	.51	13.83	13.43
Betty	2.18	2.19	11.57	14.13	.65	.62	14.40	16.94
Red III	1.78	1.70	9.85	11.84	.52	.46	12.15	14.00
Amy	1.90	1.98	10.89	12.59	.60	.59	13.39	15.16

Second Half.

Fancy III	2.48		12.87		.74		16.09	
Betty III	1.78		9.80		.52		12.15	
Ida II	1.72	As above.	9.57	As above.	.57	As above.	11.90	As above.
Betty	2.22		13.83		.66		16.71	
Red III	1.82		12.11		.53		14.46	
Amy	1.94		12.77		.61		15.32	

In Table VI will be found the total amounts of each feed in the rations consumed during the entire period by each cow. The figures in parenthesis represent the number of pounds of hay and grain wasted or unconsumed. These amounts were deducted in deriving the data which follows this table.

Table VI.
Total Amounts Consumed (Pounds).

Plus Ivory Meal Ration.

<u>Cows</u>	<u>Hay</u>	<u>Wheat Bran</u>	<u>Cottonseed Meal</u>	<u>Hominy</u>	<u>Vegetable Ivory Meal</u>
Fancy III	616	84	84	56	84
Betty III	448	56	56	28	84
Ida II	448	56	56	56	70
Betty	560(28.5)	84(5)	70(4.5)	42(2.5)	84(6)
Red III	504	56	56	28	84
Amy	532(2.5)	56	56	56	70
Total	3108(31)	392(5)	378(4.5)	266(2.5)	476(6)

Minus Ivory Meal Ration.

Fancy III	616	84	84	56	-
Betty III	448	56	56	28	-
Ida II	448(15.5)	56	56	56	-
Betty	560(16)	84(3)	70(2.5)	42(1.5)	-
Red III	504	56	56	28	-
Amy	532	56	56	56	-
Total	3108(31.5)	392(3)	378(2.5)	266(1.5)	-

The following digestion coefficients are those used in the computation of Table V and are the same as were used in Experiment A, with the exception of those for hay¹ and hominy.¹ The fodder

¹ Previously determined.

analyses, likewise used in Table V, were in each case original for this particular experiment.

Table VII.

Average Digestion Coefficients (Per Cent)

<u>Material</u>	<u>Dry Matter</u>	<u>Protein</u>	<u>Fiber</u>	<u>Nitrogen-Free Extract</u>	<u>Fat</u>
Hay	61	57	62	62	50
Bran	66	77	39	71	63
Cottonseed meal	79	84	35	78	84
Hominy	82	65	67	89	92
Vegetable ivory	87	30	70	92	45

Table VIII.

Chemical Analyses of Feeds Consumed.

Moisture Table (Per Cent)

	<u>Hay</u>	<u>Bran</u>	<u>Cottonseed Meal</u>	<u>Hominy</u>	<u>Vegetable Ivory</u>
Moisture	3.91	8.26	6.13	8.88	9.88
Dry matter	96.09	91.74	93.87	19.12	90.12
Total	100.00	100.00	100.00	100.00	100.00

Dry Matter Table.

Protein	8.66 ¹	17.09	48.33	12.01	4.27
Fat	2.66	5.77	8.79	9.15	0.99
Fiber	24.96	11.18	7.82	4.59	6.71
Nitrogen-Free Extract	56.18	58.24	27.68	71.62	86.97
Ash	7.54	7.72	7.38	2.63	1.06
Total	100.00	100.00	100.00	100.00	100.00

Original Moisture.

Moisture	10.06	11.69	6.69	9.85	10.66
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¹ Amido protein = 1.30%.

The amount of digestible dry matter in the rations may now be readily determined by multiplying the amounts fed by the percentage of dry matter from the analyses and applying the digestion coefficients.

Table IX.

Digestible Dry Matter (Pounds).

<u>Cows</u>	<u>Hay</u>	<u>Bran</u>	<u>Plus Ivory Ration.</u>		<u>Vegetable Ivory Meal</u>
			<u>Cottonseed Meal</u>	<u>Hominy</u>	
Fancy III	337.96	48.96	61.92	41.39	65.29
Betty III	245.79	27.42	41.28	20.69	65.29
Ida II	245.79	27.42	41.28	41.39	54.41
Betty	291.60	38.68	56.39	29.20	60.63
Red III	276.51	27.42	41.28	20.69	65.29
Amy	290.50	27.42	41.28	41.39	54.41
Total	1688.15	197.32	283.43	194.75	365.32
<u>Minus Ivory Ration.</u>					
Fancy III	337.96	48.96	61.92	41.39	--
Betty III	245.79	27.42	41.28	20.69	--
Ida II	273.28	27.42	41.28	41.39	--
Betty	298.45	39.65	49.80	22.94	--
Red III	276.51	27.42	41.28	20.69	--
Amy	291.97	27.42	41.28	41.39	--
Total	1687.96	198.29	276.84	195.49	--

A grand total of 2,728.97 pounds is obtained for the digestible dry matter of the Plus Ivory Meal Ration, while 2,358.53 pounds composes the Minus Ration.

Table X.Total Yield of Milk and Milk Ingredients.Plus Ivory Meal Ration.

<u>Cows</u>	<u>Time</u>	<u>Milk lbs.</u>	<u>Solids %</u>	<u>Solids lbs.</u>	<u>Fat %</u>	<u>Fat lbs.</u>	<u>Butter lbs.¹</u>
Fancy III	4 weeks	1057.2	13.00	137.43	4.67	49.37	57.6
Betty III	" "	599.0	13.55	81.16	4.72	28.27	33.0
Ida II	" "	608.4	14.38	87.49	5.33	32.43	37.8
Betty	" "	676.0	12.96	87.61	4.39	29.68	34.6
Red III	" "	312.5	15.12	47.25	5.29	16.53	18.3
Amy	" "	705.9	13.27	93.67	4.78	33.74	39.4
Total		3959.0	13.50 ¹	534.61	4.79 ¹	190.02	220.7

Minus Ivory Meal Ration.

Fancy III	4 weeks	970.1	12.52	113.56	4.26	41.33	48.23
Betty III	" "	477.1	12.95	61.78	4.49	21.42	25.0
Ida II	" "	531.7	12.95	68.86	5.16	27.44	32.0
Betty	" "	706.7	13.16	93.00	4.62	32.65	38.1
Red III	" "	433.2	14.38	62.29	5.25	22.74	26.5
Amy	" "	707.8	13.14	93.00	4.84	34.26	40.0
Total		3826.6	12.87 ¹	492.49	4.70 ¹	179.84	209.8

It will be noticed here that the ivory meal ration produced 132.4 pounds more milk than the other ration, which is an increase of 3.46 per cent. To all intents and purposes the total food consumed was identical in each ration with the exception of 470 pounds of the vegetable ivory meal. It is justifiable to conclude then, in case of this particular experiment, that the 132.4 pounds of milk was produced by the 470 pounds of ivory meal, or that it required 3.56 pounds to produce 1 pound of milk. Considering

1 An average obtained by dividing total solids or fat by the total pounds of milk.

2 Fat plus 1/6 for salt, water, etc.

5.45 cents¹ a fair average for the cost of producing 1 quart of milk, and that there are 2.14 pounds to the quart, the value of vegetable ivory meal appears to be 0.72 cents per pound, or \$14.40 per ton.

If rather less of the basal ration had been fed and more of the vegetable ivory, it is probable that the ivory meal would have given a better return in milk yield.

To concisely express the relation of the digestible dry matter consumed to the milk and milk ingredients produced by it, the following table has been prepared.

Table XI.

Plus Ivory Meal Ration.

Digestible Dry
Matter Required
to Produce

	<u>100 pounds milk</u>	<u>1 pound solids</u>	<u>1 pound fat</u>
(Pounds)	68.93	5.10	14.36

Minus Ivory Meal Ration.

(Pounds)	61.63	4.79	13.11
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About 7 pounds more digestible dry matter was required by the Plus Ivory Meal Ration to produce 100 pounds of milk.

In this experiment conclusions are drawn from the quantity and quality of milk produced before and after a definite amount of ivory meal has been removed from the daily ration. The basal ration for each cow was carefully calculated to be noticeably short of what was needed for milk and maintenance; with the addition of the ivory meal the total nutrients approximated the amount needed. Briefly stated the results of the present experiment are as follows:

1 See Mass. Bul. 145.

(a) Some 132 pounds more milk were produced by the Plus Ivory Meal Ration than by the Minus Ration, or about 3.5 per cent of the total produced.

(b) The increase was produced by the additional feeding of 470 pounds of vegetable ivory meal.

(c) As in Experiment A the average total solids and fat content of the milk produced by the Plus Ivory Meal Ration slightly exceeds those of the Minus Ration.

(d) Ivory meal has a positive value as a source of nutrition for milch cows.

Calorific Value of Vegetable Ivory Meal.

One way of estimating the value of a food is to determine its heat producing capacity. In general, the more heat produced the more energy may be derived from it. With this in mind several determinations of the calorific value of vegetable ivory were made and results compared with those of a few standard foods.

The determinations were carried out in a bomb calorimeter which was essentially the so-called Mahler-Kroecker type modified by several devices such as an electric heating coil for controlling the temperature of the outer jacket, and a spiral motor driven agitator which encircled the steel bomb itself. By means of these modifications the water in the jacket and in the bomb container could be maintained at a parallel temperature for a considerable length of time preceding the actual explosion of the bomb. Normal thermometers were used in both the jacket and bomb container. The later one was graduated into 1/100 of 1 degree between the range of 16° C. - 22° C. and an adjustable reading glass enabled one to estimate readings to 1/1000 of 1 degree.

One gram charges were used in making the tests. These were exploded in an atmosphere of oxygen by means of a short length of platinum wire heated white hot by the passage of an electric current. In making calculations, corrections were made for the amount of acid (estimated as HNO_3) formed by combustion, and the proper bomb unit¹ was deducted.

1 The water equivalent of the bomb and accessories plus the amount of water added to the bomb container.

Table I.Comparative Calorific Values.

<u>Material.</u>	<u>Small calories per gram.</u>	<u>Large calories per pound.</u>
Vegetable ivory meal	3785	1717
Corn meal ¹	3549	1610
Sugar (guaranteed) ²	3958	1753
Corn starch ¹	3692	1675

The ivory meal is shown to have a heating capacity slightly greater than corn meal and to stand about mid-way between pure sugar and pure starch. Of all the common carbohydrate foods sugar produces the greatest energy. Vegetable ivory has already been shown to be carbohydrate in nature and to contain a large amount of mannose sugar or its mother substance.

In button factories, where the largest amount of ivory waste or meal is produced, the material is used under the boilers as fuel, and it has been authoritatively stated³ that it produces about half as much heat as coal. It is interesting to note how accurately this statement is borne out scientifically. The average of twenty samples of coal recently analyzed at this station was 14,074 B. T. U., which, expressed in large calories per pound, equals 3546. This figure is approximately twice that of the vegetable ivory meal, 1717.

The relatively high position which the vegetable ivory meal holds in respect to its calorific value, assures it a good rating as an energy producing food, provided the animal is able to digest and assimilate it.

1 Jordan's Human Nutrition.

2 Bureau of Mines, Bul. 22.

3 Courtesy of Mr. C. J. Spill, Superintendent of the United Button Co., Springfield, Mass.

Conclusions.

In stating conclusively the results of the foregoing work it seems essential to group them in three sections, one representing the chemical investigations, one the digestion experiments, and one the feeding experiments.

I. Chemical Work.

1. Analyses show vegetable ivory to be carbohydrate in nature, containing about 5 per cent protein and 75 per cent nitrogen-free extract. Fat and mineral matter are negligible, while crude fiber averages 7 per cent.

2. Ninety-two and one-half per cent of the nitrogen-free extract is mannan, a polymer of mannose sugar.

3. Pentosans are present to the extent of 2.5 per cent.

4. Lignin, galactan, starch and dextran are not found in vegetable ivory,

5. A non-nitrogenous "alcoholic precipitate" amounting to about 2.5 per cent is present which is not pentose in nature. It differs from fruit "pectin" in that:-

It does not form mucic acid, and does not reduce copper.

6. By the use of Fehling's solution about .5 per cent of water soluble reducing material and 2 per cent of so-called total sugar are shown to be present.

7. The mannan in vegetable ivory is not entirely hydrolyzed without at least four and one-half hours' boiling in acid solution. The characteristic "acid" color of the solution bleaches out at the completion of hydrolysis.

8. With continued acid boiling the use of Fehling's solution gives results which, when estimated as dextrose, agree closely with the per cent of nitrogen-free extract minus the per cent

"pectin" present. Otherwise stated, practically the entire nitrogen-free extract is accounted for in the form of a hexose sugar or its condensation product, except a small percentage of pentoses.

II. Digestion Experiments.

1. Sheep ate vegetable ivory meal readily, when it was mixed with other grains, and digested it very thoroughly. Eighty-seven per cent of the dry matter and ninety-four per cent of the nitrogen-free extract was digested.

2. All the carbohydrates appeared to have been hydrolyzed and absorbed in the digestive tract.

III. Feeding Experiments.

1. Cows also ate the material when mixed with other food, without evidence of digestive disturbances. They refused to eat it if fed by itself alone.

2. It did not seem to give as satisfactory returns as corn meal, but the method of feeding employed was not entirely suited to demonstrate the exact relative values of these two materials.

3. When fed in addition to a basal ration the increase in milk amounted to about 3.5 per cent, showing its positive value as a productive food.

As an energy producer it ranks well with other carbohydrate foods and possesses a fuel value about equal to one-half that of coal.

In general it may be said that the vegetable ivory meal although very tough, tasteless and odorless, is readily eaten by sheep and cows if mixed with other grains. Sheep appear to digest it quite thoroughly, and it has been shown to increase the milk yield when fed to cows.

This work was undertaken at the suggestion of Dr. J. B. Lindsey and much credit is due him for helpful advice. The writer also wishes to express his appreciation of the advice and suggestions given by Prof. R. W. Morse and Mr. P. H. Smith.



